3.8 ECM DECEPTION ON-BOARD

The following deceptive, on-board ECM modes are contained in ESAMS 2.6.2:

a. Terrain bounce (TBC);
b. Gate Pulloff in range (RGPO), velocity (VGPO), or both (RVGPO);
c. Crosseye jamming; and
d. Wobbulation or swept square wave jamming.

Because the ECM generator is waveform driven, other modulations can be simulated via user inputs. Techniques are produced by allowing the waveform to be specified in terms of Doppler, power, phase, polarization, pulse width, and time delay. A description of the above-listed techniques is provided below.

TBC is an airborne jamming technique that generates a false target by bouncing the jamming signal off of the terrain. The geometry associated with the interaction between a TBC-equipped aircraft and a semi-active homing missile, is illustrated in Figure 3.8-1.

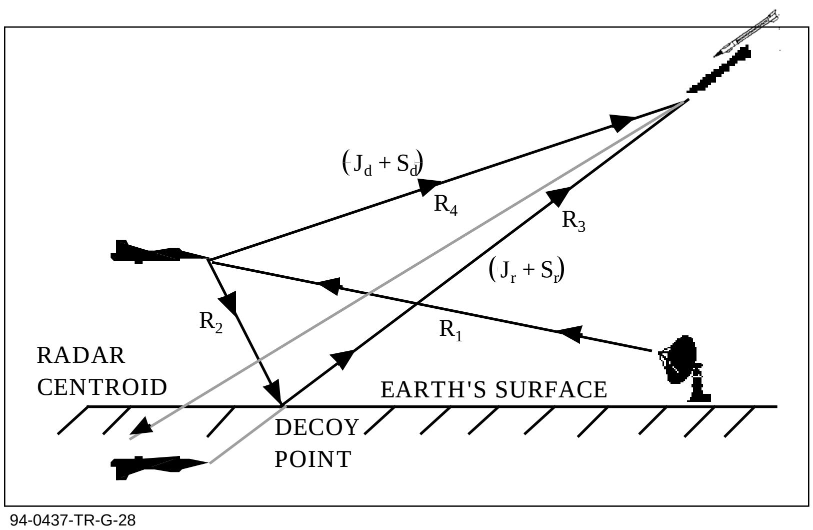

FIGURE 3.8-1. TBC Geometry.

The effectiveness of the technique is dependent upon the relative magnitudes of the direct signal ($J_d + S_d$) and the terrain-bounced signal ($J_r + S_r$) received at the missile seeker. ESAMS signal definitions are as follows:

J_d = jammer leakage
S_d = reflected illuminator signal
J_r = jammer decoy point signal
S_r = reflected illuminator multipath signal.

Significant factors in a TBC engagement are the terrain reflectivity and the scattering due to terrain roughness. In ESAMS, the Fresnel Reflection coefficient is represented as a function of grazing angle for several types of terrain and water conditions. Figure 3.8-2 illustrates the magnitude of these coefficients for different types of terrain and water.

For ground, the curves are valid from 500 MHz to 10 GHz. For water, the curves are valid only at 10 GHz, because the Fresnel coefficient will vary substantially with frequency.[1]

The nomenclatures “dry ground”, “poor ground”, “average ground”, and “good ground” in Figure 3.8-2 refer to the magnitudes of the complex dielectric constant ε_C. Dry ground would be found around Austin, Texas on a nominal day, and would have a real dielectric constant ε_r of 2.44 and an imaginary component of .001 (ref. 22). At the other end of the spectrum, good ground would have a real component of 25 and an imaginary component of .036.

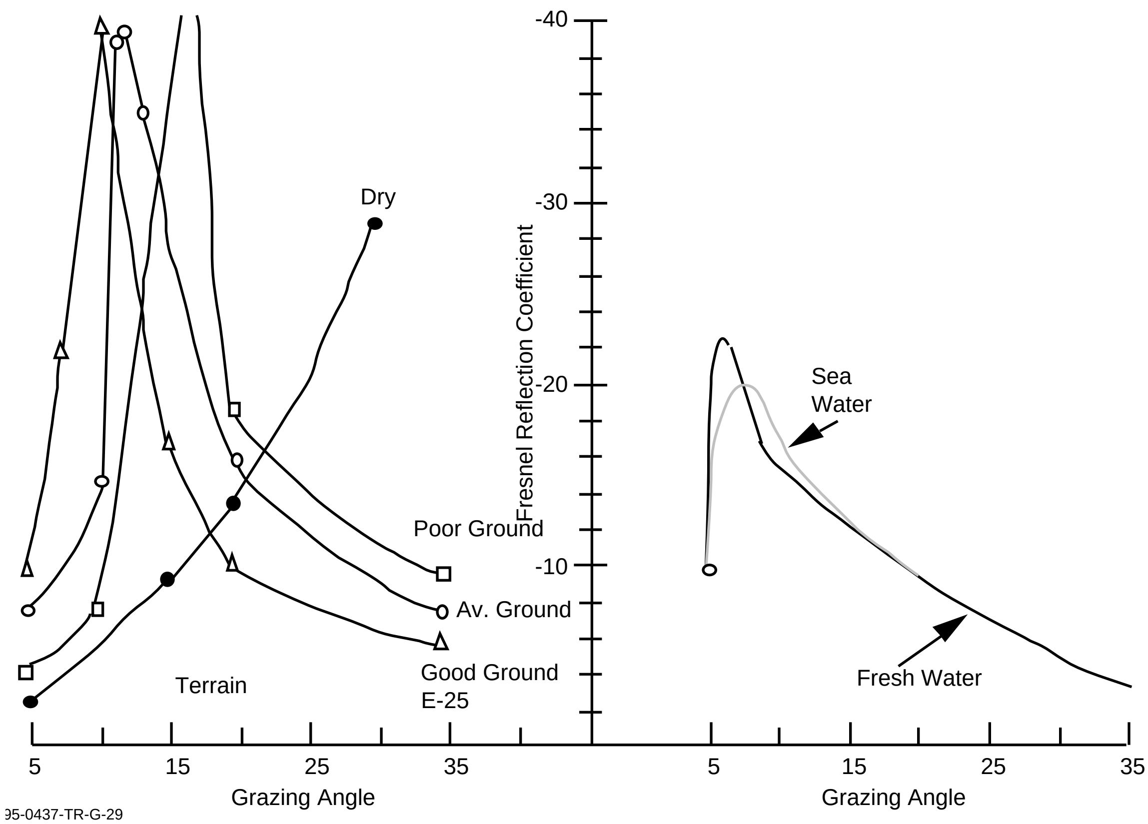

FIGURE 3.8-2. Fresnel Reflection Coefficient

The impact of terrain roughness is captured by the spatial distribution coefficient (SDC). As the terrain roughness increases, the energy spreads out in a conical pattern about the specular angle, and less TBC energy is received by the missile seeker. The SDC modeled in ESAMS is based on a theoretical development by Hughes Aircraft Company (ref. 1).[2]

1. The reader is referred to (Reference 25) for a more comprehensive discussion.

2. A comprehensive discussion of the TBC and the SDC is contained in the GRAM Analyst Manual (Ref 34). The discussion identifies the problems associated with attempting to reproduce the ref. 1 results. It also describes a “fix” that was installed for low grazing angles in order to obtain realistic results for this case.

The ESAMS TBC model ignores secondary signals such as multipath, and it determines TBC effectiveness based on the target illumination signal (S_d), the jammer leakage in the direction of the missile (J_d), and the jamming signal reflected from the terrain (J_r). The equations of interest are the following:

$$J_d = \frac{P_J G_{Jd} G_{md} \lambda^2}{(4\pi)^3 R_1^4} \qquad [3.8\text{-}1]$$

$$S_d = \frac{PGG_{md} \lambda^2 \sigma}{(4\pi)^3 R_1^2 R_4^2} \qquad [3.8\text{-}2]$$

$$J_r = Specular + DiffuseReflection = \frac{P_J G_{Jr} G_{mr} \lambda^2}{(4\pi)^2 (R_2 + R_3)^2} |R(\Psi)|^2 |F_c|^2 + \frac{P_J G_{Jr} G_{mr} \lambda^2}{(4\pi)^3} \int \frac{\sigma^o \, ds}{R_2^2 \, R_3^2} |R(\Psi)^2| |F_c^2 - 1| \qquad [3.8\text{-}3]$$

where:

PG	=	effective radiated power of target tracker (TTR)
P_J	=	jammer power
G_{Jr}	=	jammer antenna gain (r-reflected, d-direct)
G_{mr}	=	missile antenna gain (r-direction of reflection, d-direction of target)
σ	=	target RCS
σ^0	=	terrain scattering cross-section
$R(\Psi)$	=	Fresnel reflection coefficient
F_c	=	RMS specular scattering coefficient.

The integral is solved with the aid of the Hughes SDC.

The jammer leakage J_d is a key consideration. If the missile descends on the target from a well-lofted trajectory, the design of the jammer antenna pattern necessary to minimize leakage in the direction of the missile seeker will not be difficult. However, if the missile traverses a shallow trajectory, the design could be a substantial problem.

Gate Pulloff (VGPO, RGPO, RVGPO). Gate stealing involves pulling the velocity gate, the range gate, or both off of the target and then dropping the jam signal. If the procedure is successful, the radar goes into a coast mode while attempting re-acquisition. During this period, a crisp target maneuver may be effective in degrading missile intercept capability.

While older systems were not fully coordinated, newer ones have the potential to monitor the two gates to determine if the movements are consistent. If they are not, countermeasuring is suspected, and appropriate actions are taken.

In ESAMS, the ECM waveform data are stored in tables which identify how the complex voltage will be calculated and the characteristics it will have in the time and frequency domain. Figure 3.8-3 shows how the data are entered in ESAMS for coordinated range and

Doppler gate pull-off. The relative frequency and delay times are synchronized so that the velocity and range gates will be pulled off of the target in a coordinated fashion.

1. Relative Frequency (Doppler)							
	Time(s)			0.0	5.0	8.0	
	Frequency (Hz)			0.0	-4900.0	-4900.0	
2. Relative Power (J/S)							
	Time(s)			0.0	5.0	5.1	8.0
	Power (dB)			6.0	6.0	0.0	0.0
3. Relative Phase							
	Time(s)			0.0	5.0	8.0	
	Phase (Deg)			0.0	0.0	0.0	
4. Relative Polarization							
	Time(s)			0.0	5.0	8.0	
	Polarization			0.0	0.0	0.0	
5. Relative Pulse Width							
	Time(s)			0.0	5.0	8.0	
	Pulse Width			0.0	0.0	0.0	
6. Delay Time							
	Time(s)	0.0	1.0	2.0	3.0	4.0	5.0
	Delay (sec)	0.0	9.8×10^{-8}	3.92×10^{-7}	8.82×10^{-7}	1.568×10^{-6}	2.54×10^{-6}

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FIGURE 3.8-3. Model Input Data for RVGPO against a Ground Tracker.

The user can specify whether the data in the tables are to be relative or absolute. If relative is specified, the data are interpreted with respect to the target echo at the aircraft. In this context, relative power means that the jammer power is a multiple of the echo power. A value of 6 dB in the power table instructs the jammer to return a signal four times as strong as the skin power coming from the aircraft. The jammer would have to have the capability to develop this magnitude.

Crosseye Jamming. Tracking radars such as a monopulse tracker attempt to align their antenna normal to the incoming signal wavefront. The tracking angle to the target is based on this alignment. If, for some reason, the wavefront has been distorted, then tracking errors will develop. The crosseye jamming technique has the potential to develop such a distortion.

The basic concept of crosseye is illustrated in Figure 3.8-4. If there are two radiators or reflectors, there are certain geometries in which the wavefront can be distorted. These are the directions in which the magnitudes of the two energy sources are equal, but their phases differ by 180°. Thus, there is total cancellation, and, instead of a spherical propagation, there is a discontinuity.

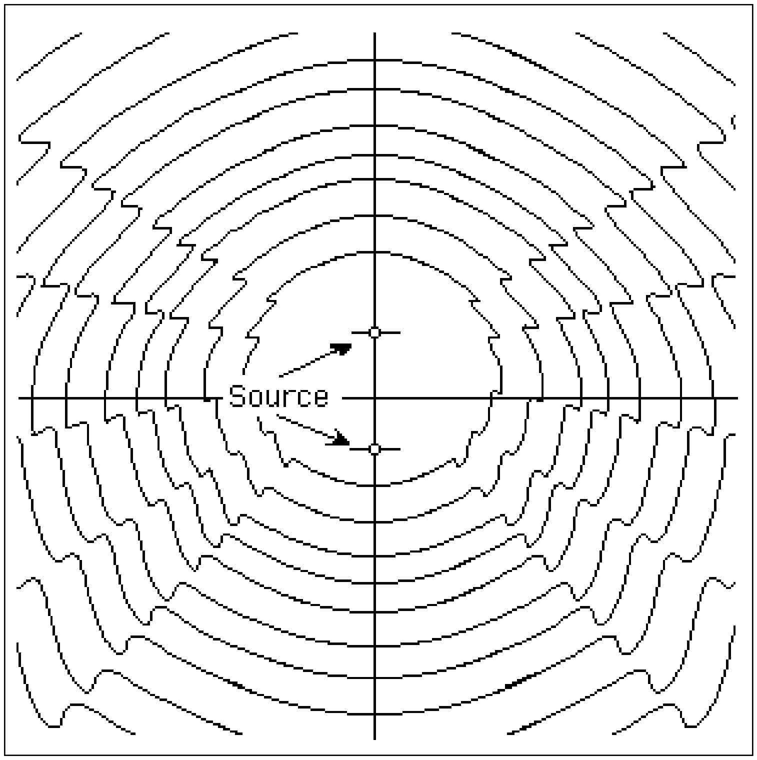

FIGURE 3.8-4. Wavefront Distortion due to Crosseye Jamming.

For monopulse radars, the angle errors are determined in the manner illustrated in Figure 3.8-5. In Figure 3.8-5, Δ is the difference channel, and Σ is the sum channel.[3] When the sum channel magnitude goes to zero, which is the result that crosseye implementation attempts to induce, the relation between the actual and measured angle off boresight is undefined. However, the radar circuitry would more than likely institute a coast mode when the sum channel signal became too small. Reference (14) states that in practice, the error due to crosseye is limited to about 0.6 times the threat's antenna beam width.

The ESAMS waveform generator for crosseye is used to develop the radiation patterns for two antennas mounted on the target aircraft. The radiators are intended to be 180° out of phase. The model evaluates the effectiveness of the crosseye technique for different victim radar locations and deviations from the desired 180° phase shift between the radiators.

3. In this relation, V is the voltage level maintained by the AGC, and K_1 and K_2 are the antenna error slopes in the sum and difference channels. For small angles off boresight, θ_m is very close to θ_A, which is the desired result.

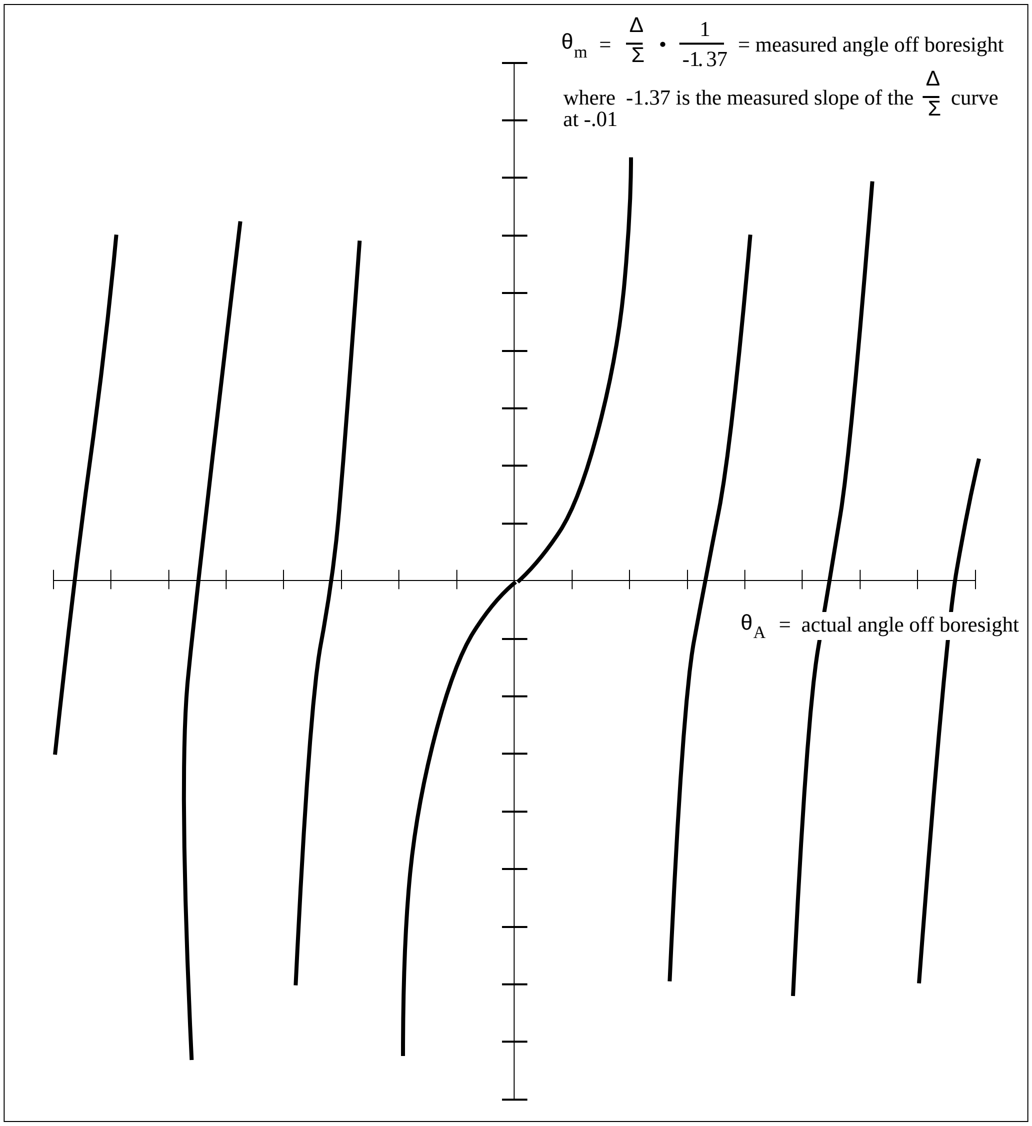

FIGURE 3.8-5. ESAMS Angle Error Extraction

Wobbulation/Swept Square Wave (SSW). Track-while-scan (TWS) systems radar are susceptible to wobbulation or amplitude modulation jamming. The specific element that is exploited is the angle discriminator portion of the tracking loop. After the TWS radar has scanned in the area of the target, the discriminator finds the centroid of the returned energy. The difference between the centroid and boresight is used as the updated command to the servo.

Figure 3.8-6 illustrates how wobbulation (SSW) works. If the radar is not being jammed, the target return is a blip. If the target aircraft is sending out barrage noise, range will be denied. If this were to occur, the radar operator would divide the strobe to get angle information, and a command guided missile would revert to 3-point guidance if it were employing the lead angle mode. Thus, this jamming employment would not be very effective.

As illustrated in Figure 3.8-6, pulse width modulation is undertaken in the SSW technique, and, if the jamming energy on one side of the target is greater than on the other, the imbalance will result in a tracking error. To be effective, the imbalance must be substantial enough to cause a significant error, and the target aircraft must be masked.

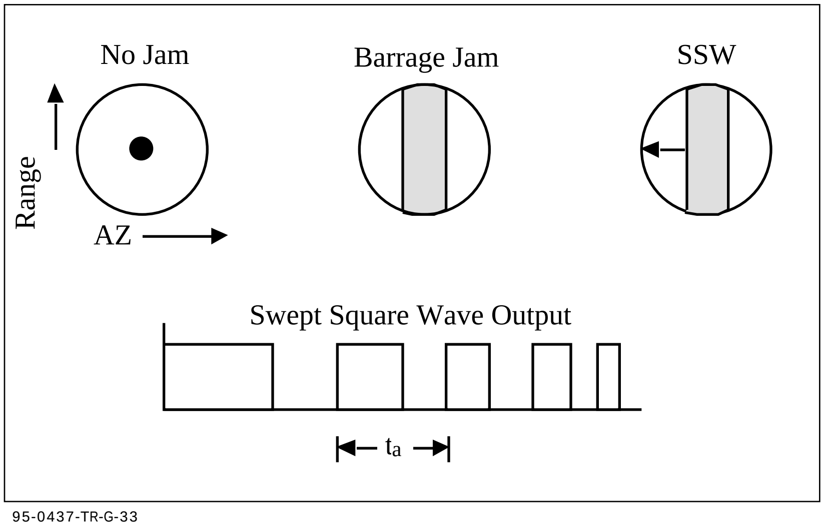

FIGURE 3.8-6. Azimuth Channel Example.

TABLE 3.8-1. ECM Deception On-Board Data Requirements.

Data Item		Accuracy	Sample Rate	Comments
1.3.2.1.1	Jammer power	±1 kW	SV/T	
1.3.2.1.2	Jammer bandwidth	±0.5 dB	SV/T	
1.3.2.1.3	Target signal		SV/T	
1.3.2.1.4	Jammer signal		SV/T	
1.3.2.1.5	Burn-through range		SV/T	
1.3.2.1.6	Jammer antenna gain		1 deg Az by 1 deg E1/step	
1.3.2.1.7	Jammer angle		10 Hz	
1.3.2.1.8	Detection time		SV/T	
1.3.2.1.9	Time amplitude modulation		10 Hz	
1.3.2.1.10	Frequency		10 Hz	
1.3.2.1.12	Phase		10 Hz	
1.3.2.1.13	Angle error		10 Hz	
1.3.2.1.14	Range error		10 Hz	